Changes in the Status, Distribution, and Management of Double-Crested Cormorants in Wisconsin

By Sumner W. Matteson, Paul W. Rasmussen, Kenneth L. Stromborg, Thomas I. Meier, Julie Van Stappen, and Eric C. Nelson

Abstract: We reviewed and summarized historical data and conducted population surveys from 1973 through 1997 to determine the breeding status and distribution of double-crested cormorants *(Phalacrocorax auritus)* in Wisconsin. Breeding cormorants historically occupied large, isolated lakes and wetlands in northern Wisconsin, but there were no known nesting sites until 1919, when cormorants were reported nesting on Lake Wisconsin in south-central Wisconsin. From the 1920's to the 1950's, cormorants occupied 17 colony sites in 16 counties, though no more than 7 sites were occupied during any particular year. From the 1950's to the early 1970's, the number of cormorant nests and colony sites plummeted owing to bioaccumulation of dichlorodiphenyltrichloroethane (DDT) and its metabolites, human persecution at some colony sites, and habitat loss. The installation of 1,269 artificial nesting platforms at 13 locations in north-central, northeastern, northwestern, east-central, and southwestern Wisconsin, coupled with a decline in dichlorodiphenyltrichloroethane (DDE) levels in breeding birds, as well as protection as a State-endangered species, led to a marked recovery. Between 1973 and 1997, the State's breeding population grew at an annual rate of nearly 25 percent, from 66 nests at 3 colony sites to 10,546 nests at 23 colony sites. We estimated population trends for six geographic regions in the State determined by distinct distribution patterns of nesting birds. Cormorant populations for five of six regions increased during 1973 through 1997. Trends differed significantly among regions, with a greater estimated increase in Great Lakes' sites ($P < 0.01$). In 1997, 81 percent of the State's breeding population occurred on four islands in Green Bay on Lake Michigan. Increasing Lake Michigan cormorant populations have raised concerns among sport and commercial fisheries about impacts on yellow perch *(Perca flavescens),* although recent studies indicate that alewives *(Alosa pseudoharengus)* predominate in cormorant diets.

Keywords: contaminants, distribution, double-crested cormorants, fisheries, flowages, Great Lakes, *Phalacrocorax auritus,* population, productivity, wetlands, Wisconsin

Changes in the status and distribution of Wisconsin's double-crested cormorant (DCCO) breeding population during the 20th century closely approximate a similar pattern throughout the Great Lakes and generally along the Atlantic coast: a gradual increase in population size from about 1921 until about 1950, followed by a population crash, and then a remarkable population resurgence beginning in the early 1970's (Matteson 1983, Hatch 1995, Weseloh et al. 1995).

Management of breeding DCCO's in Wisconsin focused on providing suitable nesting structures at a time (1970's) when the species was listed as endangered in the State. In the early 1980's, when a rapidly expanding cormorant population was perceived as a serious threat to the commercial harvests of common whitefish *(Coregonus clupeaformis)* on Lake Superior, management focused on deterrents at pound net structures and research on cormorant diets (Craven and Lev 1987). Diets of Lake Michigan cormorants were also investigated. As the Wisconsin DCCO breeding population continued to increase in the 1990's, concerns about impacts on Lake Michigan fisheries, particularly yellow perch populations, resulted in further examination of cormorant diets.

Here we review the changes in DCCO population size and distribution in Wisconsin since 1900, detailing the marked increase in numbers of nesting cormorants since 1973 and summarizing management and research efforts to date.

Study Area

In Wisconsin, DCCO's breed in Lakes Superior and Michigan watersheds, large inland flowages and lakes, and the Wisconsin portions of the Mississippi and Wisconsin rivers. Thus, much of the State of Wisconsin was included in the study area, and we identified and monitored six regions associated with some of Wisconsin's major watershed and wetland complexes. These included the Apostle Islands, Lake Superior (API); Green Bay–Lake Michigan (GBLMI); Upper Mississippi River (UMISS); Horicon Marsh–Grand River Marsh–Lake Puckaway in east-central Wisconsin

(EACE); St. Croix River and associated areas in Burnett County, northwestern Wisconsin (BUCA); and the Wisconsin River and associated areas in central and north-central Wisconsin (CE–NC) (fig. 1). Portions of these regions were first noted by Anderson and Hamerstrom (1967) when they summarized historical occurrences and reported results from the State's first statewide DCCO population survey.

The vegetation of all six regions where DCCO's occur in Wisconsin is characterized by even-aged hardwood stands or mixed hardwood–conifer stands; snags are abundant in some locales. Extensive river and lake ecosystems support a variety of potential fish prey species—particularly forage fishes—in each region. Undisturbed island habitats varying from tree covered to open, cobble beach or rocky shoreline are characteristic of most regions. Tree thinning or losses at island sites where DCCO's nested for 10 years or more have occurred owing to the combined effects of cormorant excreta killing vegetation and severe storms causing blowdowns.

Methods

Before 1973, and especially from the late 1940's to the early 1970's, State conservation officials, University of Wisconsin (UW) and Milwaukee Public Museum ornithologists, and Wisconsin Society for Ornithology (WSO) observers reported the occurrences and number of cormorants nesting in the State or the disappearance of breeding cormorants from formerly active sites. The WSO Research Committee undertook the first systematic statewide survey of cormorants in 1966, largely soliciting reports from WSO members and State conservation officials. The results were reported the following spring by Anderson and Hamerstrom (1967).

Since 1973, a collaborative network of managers and researchers from the Wisconsin Department of Natural Resources (WDNR), U.S. Fish and Wildlife Service (FWS), U.S. National Park Service, UW, and WSO contributed statewide information on colony locations, size, and production. Beginning in 1983, we used standardized data forms for recording colony size, type (ground, tree, artificial nesting structure), clutch size, and young produced.

We use the terms *active nests* and *nesting pairs* interchangeably in describing the size of each cormorant colony. Similar to how Weseloh et al. (1995) used the term, an active nest is one observed with eggs or young, or one that appears to have been used (eggshell fragments present, recent nesting material used, and feces or prey remains present) during the breeding season. For each colony, the estimate of the number of nesting pairs was based on the highest number of active nests counted during a single visit (Milton and Austin–Smith 1983), although for colonies visited more than once, the maximum number of active nests recorded at any one time provided an estimate of the minimum number of nesting pairs present (Postupalsky 1978).

Except at a Lake Michigan colony censused by Stromborg (concerned about the effects of daytime human disturbance), all colonies were visited during daylight hours. All colonies were visited one or two times, sometimes three or more times, between late May and early July. Depending on location, we surveyed colonies by boat, by airplane, on foot, and with binoculars from nearby roads. Sites surveyed by air were usually ground-truthed.

Using methodology similar to that of Weseloh et al. (1995), we obtained productivity data from colonies when young were generally about 3 or more weeks old. Productivity data were incomplete for several sites. Means for young produced were computed for 1974 through 1997; each year was given equal weight.

Breeding Population Size, Trends, and Distribution

Statewide estimates of breeding DCCO's in Wisconsin were compiled from nest censuses conducted annually during 1973 through 1987—from 1 year after the bird was listed as State endangered until 1 year after it was delisted because of a remarkable recovery.

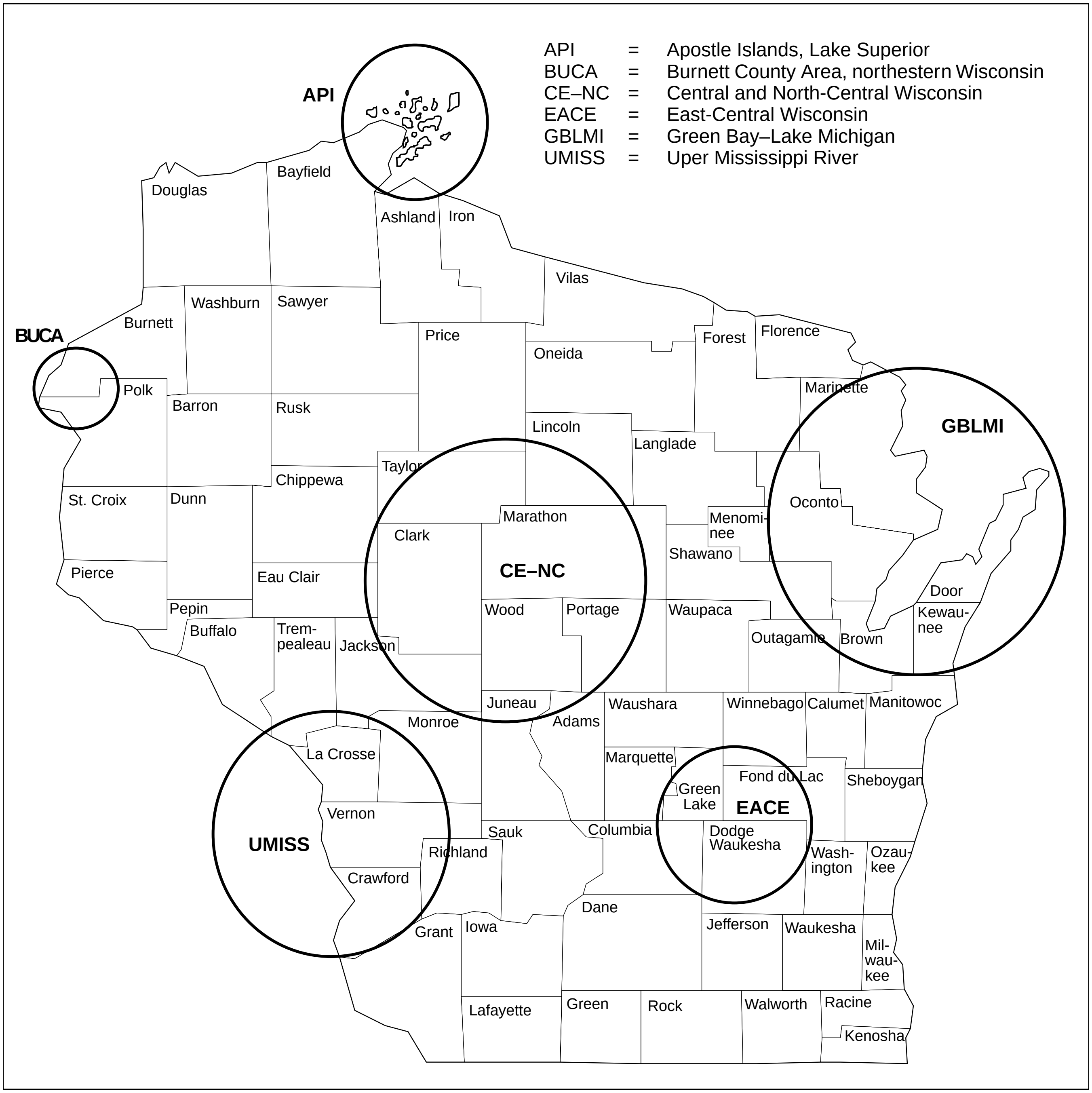

Figure 1—Wisconsin double-crested cormorant study area, 1973–97. Cormorants also occurred in these regions prior to the 1960's, as first noted by Anderson and Hamerstrom (1967).

Additionally, we censused the number of cormorant nests statewide in 1994 and 1997. We computed statewide totals by combining counts across all sites in the State. We used data from all years (n = 20) in which 5 or fewer of the 46 total sites in the State were missed. Thus, statewide totals for many of these years are slight underestimates of the number of active cormorant nests.

We estimated population trends from 1973 to 1997 for the six regions (API, BUCA, CE–NC, EACE, GBLMI, UMISS) described in the study area section. Not all active colonies were surveyed annually (table 1). Some Great Lakes colonies and inland colonies, however, were monitored, censused, or both each year from 1973 to 1997. Within each region, we combined nest counts across all sites surveyed to obtain a total for each region each year. We did not use annual totals when more than one or two sites were not surveyed in a region.

We grouped data from regions into two strata: *Great Lakes* and *Inland* (representing interior colonies located away from the Great Lakes basin). We again combined counts across all sites to obtain a total for each stratum in each year. We used data for 12 years from Great Lakes sites (10 years with all sites surveyed, 1 year with one site missing, 1 year with two sites missing). We used data for 8 years from the Inland sites (6 years with all sites surveyed, 1 year with one site missing, 1 year with three sites missing).

Analysis

We estimated statewide or regional trends directly from statewide or regional nest counts because cormorant nests could be counted at all colonies in Wisconsin. We estimated cormorant population trends using a regression model of the form $\log(\text{count}) = b_0 + b_1 * \text{year} + \text{error}$, where the error is assumed to be normally distributed with a mean of zero and a constant variance. We did not adjust for serial correlation among successive counts. Missing data due to years in which all colonies were not surveyed lessened the effect of serial correlation and also reduced degrees of freedom, thus resulting in more conservative tests but did not bias trend estimates. We back-transformed the slope estimates and 95-percent confidence limits using methods described by Geissler and Sauer (1990).

Table 1. Percent annual change in Wisconsin's breeding double-crested cormorant population, 1973–97

Region	Number of sites	Number of years used in analyses	Percent annual change (95-percent confidence interval) 1973–85		1986–97		1973–97	
Great Lakes	**17**	**12**	**62.6**	**(36, 98)**	**15.5**	**(12, 19)**	**35.3**	**(24, 47)**
API	3	20	83.6	(60, 111)	4.8	(0, 10)	39.7	(27, 53)
GBLMI	14	14	57.2	(32, 88)	16.6	(12, 21)	33.1	(25, 41)
Inland	**29**	**8**	**23.1**	**(16, 31)**	**4.5**	**NED[1]**	**11.9**	**(7, 18)**
UMISS	7	15	48.0	(34, 64)	–19.1	(–68, 104)	18.4	(7, 31)
EACE	8	16	19.7	(9, 31)	10.6	(2, 20)	16.3	(12, 20)
CE–NC	9	14	29.3	(24, 35)	–3.9	(–10, 3)	11.7	(6, 17)
BUCA	5	21	9.3	(3, 16)	1.5	(–10, 15)	–17.2	(–22, –12)
Wisconsin	**46**	**20**	**36.9**	**(33, 41)**	**13.2**	**(10, 16)**	**24.7**	**(21, 28)**

API = Apostle Islands, Lake Superior; GBLMI = Green Bay–Lake Michigan,
UMISS = upper Mississippi River, EACE = east-central Wisconsin;
CE–NC = central and north-central Wisconsin,
and BUCA = Burnett County area, northwestern Wisconsin.

[1]NED = not enough data to estimate 95-percent confidence interval.

Colony differences were influenced by observer effects: because most colonies were surveyed by one observer for the entire period, it was not possible to adjust for such effects. We examined residuals and predictions from regression models to determine if assumptions of the regression models were satisfied. We believe that estimates from linear regression models may provide useful summaries of population trends even when there is evidence for some deviation from the linear model. We used analysis of covariance (ANCOVA) to test for differences in slopes among regions or between strata. We used SAS (SAS Institute 1990) for all computations.

Management

On the basis of communications (published and unpublished reports, personal communications) to and from the WDNR, we summarized the history and use of artificial nesting platforms attached to used utility poles (generally 5–11 m in height) to replace fallen or unstable nest trees and to increase cormorant populations. The platform design used was a lath structure with a 2-m-long perch; sticks wired to the lath provided incipient nesting material (Meier 1981).

The use of deterrents at pound nets frequented by DCCO's in the Apostle Islands, Lake Superior, has been described in detail by Craven and Lev (1987). Given the historical perspective of our chapter, we briefly summarize key results of that study and comment on events since Craven and Lev's work.

Results

Breeding Population Size and Trends

Despite reports indicating that cormorants historically were common nesters in some of the more isolated and larger lakes of northern and central Wisconsin (Kumlien and Hollister 1903, Anderson and Hamerstrom 1967) and that cormorants probably bred here during the first part of the 1900's (Anderson and Hamerstrom 1967), there were no published reports of colony sites until 1919 and 1921 (Williams 1957, Matteson 1983). A colony occurred both years on Lake Wisconsin (formerly known as the Okee Flowage) in southwestern Columbia County of south-central Wisconsin (Anderson and Hamerstrom 1967, Williams 1957). The number of cormorant nests in 1919 was unknown, but in 1921, 13 pairs nested on the Okee Flowage in dead trees (Stoddard 1921, 1922), the first recorded data on cormorant nestings in Wisconsin.

From 1921 to the mid-1960's, DCCO's occupied 17 known colony sites in 16 counties, though apparently no more than 7 colony sites were active during any season (Matteson 1983, 1986). The 16 counties (and corresponding years) with colonies were as follows: Adams—1923, 1952–57, 1960; Bayfield—1956; Burnett—1952–63, 1966; Columbia—prior to 1955; Dodge—1954–58; Door—up to the early 1960's; Grant—1955; Jackson—1961–66; Juneau—1957–63; Marathon—1939–66; Marinette—up to the 1950's; Oneida—prior to 1952–53; Sauk—1921, 1932; Sawyer—1939; Trempealeau—1939; and Wood—1954–57 (Anderson and Hamerstrom 1967, Matteson 1983). The total number of nesting pairs statewide reached at least several hundred in peak years, although exact numbers were unknown.

Observations of several thousand migrants were common during the spring and fall in the 1940's and early 1950's (Anderson and Hamerstrom 1967). By 1966, however, only 3 active colony sites with a total of 24 nesting pairs were identified (Anderson and Hamerstrom 1967). In 1972, the DCCO was officially listed as State endangered (Matteson 1983).

In 1973, a statewide survey revealed 66 nesting pairs at 3 colony sites in central, south-central, and northwestern Wisconsin (Grand River Marsh Wildlife Area [WLA], Mead WLA, and Crex Meadows WLA) (Jurewicz 1979). Two of three colonies active in 1966 were active in 1973, and the number of nests had increased. In northwestern Wisconsin, the Crex Meadows colony grew from 7 to 23 nesting pairs. The Mead WLA colony increased from 5 to 20 pairs.

At a former colony closely associated with Mead WLA—Lac du Bay—there were 300 nesting pairs in 1949; the colony gradually declined, and only 5 active nests were reported at Lac du Bay in 1966 (Anderson and Hamerstrom 1967). The Lac du Bay colony site—first discovered in 1939 by Barger (1940)—was only about 10 km from the present-day Berkhahn Flowage (formerly Townline Flowage) cormorant colony at the Mead WLA (Brian Peters, pers. commun.). Knudsen (1951) observed about 400 nests of cormorants and great blue herons *(Ardea herodias)* combined in 1949 and 1950 at the Lac du Bay site and about 259 in 1951. This colony was abandoned between 1966 and 1972, and the remaining cormorants apparently emigrated to the Mead WLA (Jurewicz 1979).

By 1976, there were two new colony sites and a total of six active colonies in the State. The Crex Meadows colony was no longer active; instead, nesting cormorants apparently relocated to the Fish Lake WLA in southwestern Burnett County. For the first time in about 15 years, nesting cormorants returned to an island site (Fish Island) off the Door County peninsula. And for the first time in 35 years, cormorants nested in the Wisconsin waters of the Mississippi River at what is now the Trempealeau National Wildlife Refuge. The State's breeding population in 1976 had increased 98 percent since 1973, to 131 pairs.

By 1979, the number of nesting pairs statewide had increased to 460 (up 251 percent since 1976) at 7 colonies, and there were 3 additional, uncensused, active colony sites. For the first time in 22 years, cormorants nested in the Wisconsin waters of Lake Superior. A colony of 17 pairs was established in 1978 on Gull Island of the Apostle Islands (Stanley Temple, pers. commun.) and increased to 41 pairs in 1979 (Matteson 1979 unpubl.). In east-central Wisconsin, there were two new colonies at Horicon National Wildlife Refuge and at the Horicon Marsh WLA.

By 1982, there were five new (since 1979) colonies in central and north-central Wisconsin and two in Green Bay. The State's nesting population had increased 123 percent since 1979 to 1,028 pairs in 16 colonies. Owing to the species' comeback, its official State status changed from "endangered" to "threatened."

By 1985, the State's breeding population had reached 2,213 nests in 21 colonies, and 1 additional colony was active but not censused; a lone pair in Clark County brought the total to 2,214. Six additional colonies had appeared: in Green Bay, in Burnett County in northwestern Wisconsin, on the Mississippi River, in the Apostle Islands, on Lake Puckaway in east-central Wisconsin, and on the Chequamegon Water's Flowage in north-central Wisconsin.

By 1989, the State's breeding population had increased 59 percent to 3,515 nests since 1985, but this was a conservative estimate because 5 known active colonies were not censused. The total number of active colonies dropped slightly to 20. Two Burnett County colonies, Grand River Marsh, three Green Bay sites, and two sites in central and north-central Wisconsin were no longer active. And the Horicon National Wildlife Refuge (NWR) site had apparently shifted to the Horicon Marsh WLA. Offsetting these changes were three recently established sites on the Mississippi River, two on Green Bay islands, and a second colony on Lake Puckaway, which was most likely attracting birds that had formerly nested at Grand River Marsh.

By 1993, Wisconsin's breeding population stood at 6,481 nests—an 84-percent increase since 1989—with a new colony established at Horicon NWR, 2 new colonies along the Mississippi River, 2 new colonies on islands off the Door County peninsula in northeastern Wisconsin, and a new colony in Burnett County. One north-central site and a Green Bay island site were no longer active.

In 1997, the State's breeding population reached 10,546 at 23 colonies—a 63-percent increase since 1993 and nearly a 160-fold increase since 1973. There was an average annual population increase of 24.7 percent over the 25-year period (table 1, fig. 2). The annual rate of increase was significantly greater, however, during 1973 through 1985 than 1986 through 1997: 36.9 percent compared with 13.2 percent, respectively ($P < 0.05$). The total number of colonies

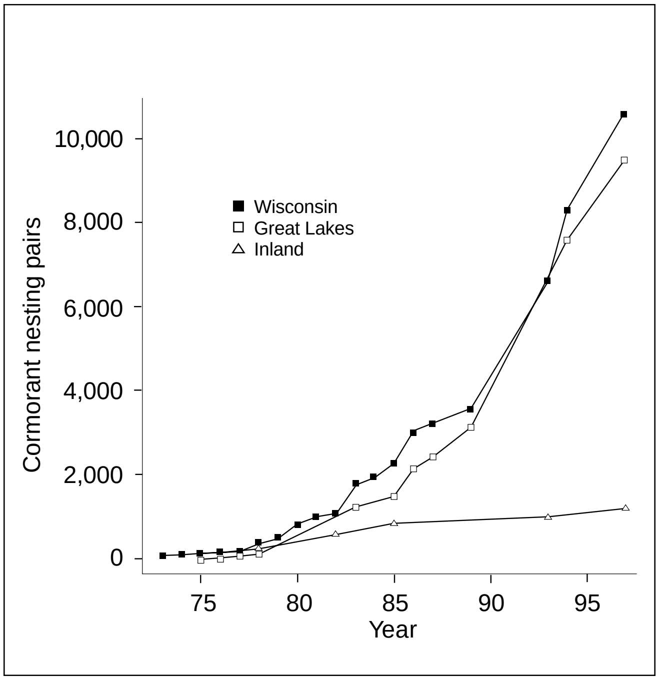

Figure 2—Double-crested cormorant nesting pairs in Wisconsin, 1973–97. Total number of pairs is shown separately for inland and Great Lakes strata and for the State as a whole. Total number of pairs for inland and Great Lakes strata is not included for years when two or more sites were not counted. Total number of pairs for the State is not included when more than five sites were not counted. Lines connecting points are merely a visual aid and are not intended to represent estimates.

during this period increased from 3 in 1973 to a high of 24 in 1993 (appendix A). Since 1993, colonies had become inactive at two Mississippi River sites, at a north-central site, and in Burnett County. There was one new small island colony in Green Bay, one new site in north-central Wisconsin, and a third colony site at Horicon NWR (appendix A).

Cormorant populations increased over the 25-year period 1973–97 for all regions except BUCA, but UMISS and CE–NC populations had declined since the mid-1980's (table 1, fig. 3). The API population had declined since the early 1990's. There were significant differences in trends among regions during the entire 25-year period: Great Lakes sites increased, inland sites (except for BUCA) increased slightly, and BUCA decreased ($P < 0.01$).

Comparing the two periods, 1973–85 and 1986–97, we found that cormorant populations continued to increase in both strata—inland and Great Lakes—during 1986 through 1997 (table 1, appendix A), but the increase was significantly greater on Great Lakes sites, particularly Green Bay and Lake Michigan sites ($P < 0.002$). The annual growth rate for GBLMI colonies, however, dropped significantly—from 57.2 percent to 16.6 percent for periods 1 and 2, respectively ($P < 0.001$). Residual plots suggest that the annual rate of increase declined after the mid-1980's in each region where the population continued to grow. The API population grew at an annual rate of 83.6 percent during period 1 and declined sharply during period 2 to a 4.8-percent rate of increase ($P < 0.001$). The EACE population grew at an annual rate of 19.7 percent during period 1 but dropped to 10.6 percent during period 2. Colonies disappeared from BUCA during period 2. The CE–NC and UMISS populations, after period 1, exhibited significant declines ($P < 0.001$) (table 1).

Large increases in nest numbers since the mid-1980's occurred at four GBLMI sites (figs. 3 and 4), and the total number of nests on the Spider Islands, Cat Island, Hat Island, and Jack Island (fig. 4, appendix A) accounted for 81 percent of the State's total breeding population in 1997.

Despite increasing cormorant nesting populations in all regions except BUCA, many inland colony sites (n = 20) declined in number or became inactive during 1986 through 1997 (appendix A). These declines reflected a shift to new sites, an increase in number at other existing sites, or other factors acting in concert or independently, such as great horned owl *(Bubo virginianus)* predation and loss of nesting trees, snags, and artificial nesting structures to storm activity and erosion. Along the upper Mississippi River, the number

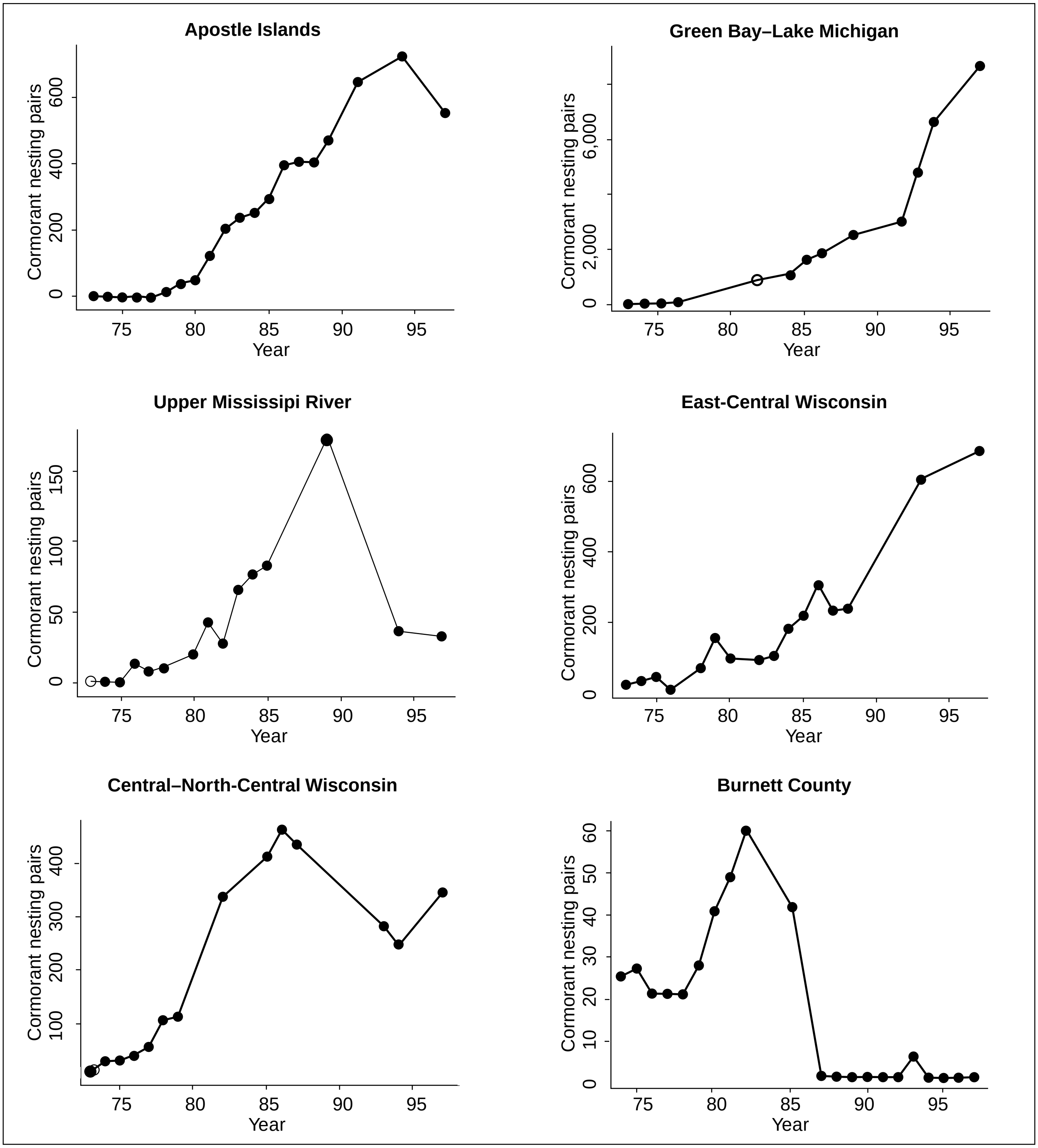

Figure 3—Cormorant nesting pairs counted in each region of Wisconsin, 1973–97. Total nesting pairs are not shown for years when two or more colonies in the region were not counted. Lines connecting points are merely a visual aid and are not intended to represent estimates.

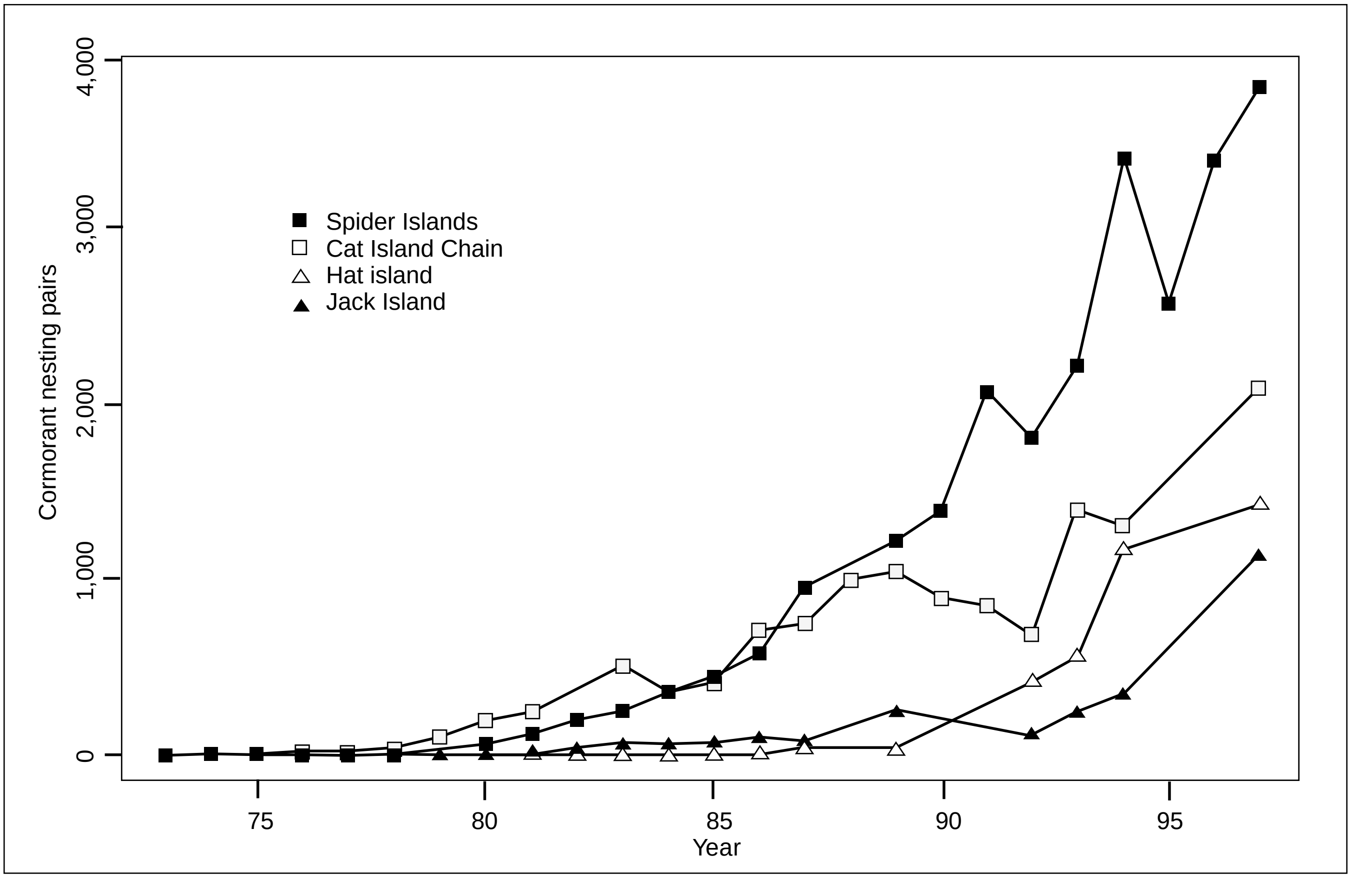

Figure 4—Cormorant nesting pairs counted at the four largest island colonies on Lake Michigan (including Green Bay), Wisconsin, 1973–97. Lines connecting points are merely a visual aid and are not intended to represent estimates.

of cormorant colonies on the Wisconsin side of the river declined 60 percent since 1989, and the total number of nests dropped from 175 in 1989, the peak year for number of colonies (5), to 35 in 1997 (appendix A).

Breeding Distribution

During the periods 1940–66 and 1973–79, inland colonies supported more nesting cormorants than Great Lake sites. Beginning in 1980, however, the total number of known active nests on the Great Lakes annually surpassed the total from all inland sites combined (fig. 2, appendix A). By 1990, the Great Lakes population was about five times as large as the inland population, and numbers had increased exponentially.

Comparing distribution of nests within each of six regions during the periods 1973–85 and 1986–97, we found a marked shift in the proportion of total number of nests. In 1985, 51.3 percent of the nesting population occurred in GBLMI; 19.4 percent occurred in CE–NC; 13.6 percent occurred in the API; 10.3 percent occupied sites in EACE (Horicon Marsh–Grand River Marsh); and the remaining 3.8 percent and 1.6 percent colonized sites in the UMISS and BUCA regions, respectively. By 1997, GBLMI accounted for most of the State's breeding population: 84.1 percent, followed by EACE (Horicon Marsh–Lake Puckaway)—6.7

percent, API—5.4 percent, CE–NC—3.5 percent, and UMISS—0.3 percent.

Productivity

Statewide, production of young during 12 of the 13 years between 1973 and 1985 ranged annually from a mean of 0.00 to 2.85 young/nesting pair, and the weighted mean was 1.73. During 1986 through 1997, annual production ranged from a mean of 0.00 to 3.26 young/nesting pair, and the weighted mean was 1.50. In total, for all 24 years, mean annual production per nesting pair was 1.58.

Average annual productivity in the CE–NC ranged from 1.27 to 2.85 young/nesting pair during the mid-1970's to the late 1980's. But since 1989, several poor seasons occurred with the mean number of young per pair exceeding 0.78 twice only (appendix B). In the BUCA, there was excellent productivity in the early 1980's, followed by complete nest failures and then total abandonment of colony sites by 1986.

In the EACE, average productivity ranged from 0.73 to 3.10 young per nesting pair during 10 of 11 years from 1979 to 1997. Colony sites within the UMISS experienced relatively less success than CE–NC sites, with productivity at 0.37 young per pair or less for 3 of 11 years during 1976 through 1996, but with values ranging from 1.07 to 2.36 young/pair for the other 8 years.

On the Great Lakes, colonies in the GBLMI and API experienced similar success in the mid-1980's. Beginning in 1989, however, the Apostle Islands' largest colony experienced very poor productivity until 1994; one year (1992), 262 cormorant young had to be buried after an outbreak of Newcastle disease. There was poor productivity in the GBLMI area during the mid-1970's, but mean annual productivity ranged from 1.16 to 3.26 young/nesting pair for 13 years during 1978 through 1997 (appendix B).

Management

Artificial Nesting Platforms—During the period 1974–76, the WDNR installed 126 cormorant artificial nesting platforms at the Mead WLA in north-central Wisconsin. These were the first artificial nesting structures installed for breeding cormorants in Wisconsin, and the first management effort directed at providing secure cormorant nesting sites. The number of pairs at Mead increased from 20 in 1974 to a peak of 448 in 1986. Mean fledging rates ranged from 1.27 to 2.85 young/pair during 1973 through 1985. But during 1986 through 1997, productivity ranged from 0.00 to 2.07. There were at least 4 years of no production beginning in 1989 (when storms were also a factor), owing largely or exclusively to predation by great horned owls. Cormorants have occupied two Mead flowages since the early 1970's: Berkhahn Flowage and Teal Flowage. Including the history of the Lac du Bay colony, formerly only about 10 km from Berkhahn, there have been a record 58 consecutive years of nesting in the area—the longest continuous period of cormorant breeding in the State—from 1939 to 1997.

Between 1974 and 1984, 1,269 platforms were installed at 13 locations in the State, but in 1984 the actual number available to cormorants was 794 at 11 locations, reflecting losses due to storm activity, high winds, ice movement, and in Green Bay, high water levels. Of these, 505 contained active nests in 1984—and 6 great blue heron platforms contained nests—representing a total of 26.8 percent of the State's breeding population (1,903 nests, Matteson 1985) at 6 sites. Of the remaining distribution of nest types in 1984, 735 (38.6 percent) occurred on the ground and in shrubs and 659 (34.6 percent) occurred in live trees and snags.

As the cormorant population continued to increase between 1984 and 1997, no additional platforms were installed, and little or no effort was made to maintain existing platforms. In 1997, the number of platforms available and in use was 249 at

4 sites—a 69-percent reduction in the number of available platforms and a 51-percent reduction in platforms used in 1984 at 2 fewer sites. During 1997, the distribution of nest types was as follows: 249 (2.4 percent) nests occurred on platforms, 8,980 (85.1 percent) occurred on the ground and in shrubs—close to a 12-fold increase since 1984, and 1,317 (12.5 percent) were in trees and snags—about a 100-percent increase in the number of nests in trees and snags since 1984 but a marked decrease in the relative proportion of nests in trees and snags.

Cormorant Deterrents at Pound Nets—In 1982, 5 API commercial fishermen estimated that 30 to 40 percent of their pound-net catch of common whitefish was lost because of cormorant depredation activities at 40 nets (Matteson 1983, Craven and Lev 1987). In 1983 and 1984, Craven and Lev (1987) tested nine techniques (audio scare device, electrified wires, metal cones on tops of poles, nail on tops of poles, owl decoy, Mylar™ helium balloons, hanging scarecrow, boat floating in pot of net, and scarecrow in a dinghy). The researchers found that certain scare devices (scarecrow or dummy) combined with others (cones, nails, electric shocker) rendered API pound-net poles inaccessible and proved successful in deterring cormorants for periods of up to 4 weeks before the birds habituated to them.

Discussion

Three factors contributed to a steep decline in the number of nesting DCCO's between the mid-1950's and early 1970's: (1) habitat deterioration in the form of tree losses and thinning; (2) reproductive failures associated with the effects of chlorinated hydrocarbon residues, particularly DDT and its metabolites DDE and DDD (dichlorodiphenyldichloroethane) (Anderson and Hamerstrom 1967, Anderson et al. 1969, Postupalsky 1971 and 1978); and (3) human disturbance, especially unsanctioned taking of nests, eggs, and young by commercial fishermen off the Door County peninsula in northwestern Wisconsin. Fishermen believed cormorants frequenting pound and other nets posed a serious threat to their livelihood. In central Wisconsin, illicit cormorant shoots became popular (Anderson and Hamerstrom 1967, Matteson 1983). Corresponding population declines for similar reasons occurred throughout the Great Lakes region (Weseloh et al. 1995, Ludwig and Summer 1997).

Wisconsin's current breeding population has surpassed any known historic population level, and it will likely continue to expand for some time to come, although the annual rate of increase is declining. A pattern similar to what is occurring elsewhere on Lake Michigan, as well as on Lake Ontario, is most likely operative. As breeding habitat becomes saturated, the immigration rate declines; this results in a lower annual population growth rate while the absolute total number of cormorants continues to increase (Weseloh and Ewins 1994, Ludwig and Summer 1997). This pattern is especially apparent in the Wisconsin waters of Lake Michigan, where the number of nesting cormorants on four island sites is driving the State's population growth rate. If epizootic diseases such as Newcastle disease, however, assert themselves on these islands, such as occurred on Gull Island in the Apostle Islands in 1992—part of a larger outbreak from the Rocky Mountains east to Quebec and Maine (Ludwig and Summer 1997)—then population growth may be seriously affected. Annual reproductive output of 0.8 young/nesting pair (Ludwig et al. 1995) or 1–2 young/nesting pair (Dunn 1975) is believed necessary to maintain population stability.

In the mid-1980's, population modeling, using sigmoidal or logistic growth models, forecast a State breeding population that would stabilize at about 3,249 nesting pairs by the year 1995 (Mike Staggs, pers. commun.). This conclusion was based on the assumption that certain parameters, such as recruitment rates, would remain constant. Density-dependent factors, such as competition with gull species for nesting sites, and limited food resources theoretically would become manifest around 1990. Also in the mid-1980's, Craven and Lev (1987) suggested that the growth of the API Gull Island site would follow a logistic growth pattern, with the number of nests stabilizing at about 324 pairs in 1989. In 1994, that colony peaked at 602 nests and appears now to be leveling off (appendix A). What happened to affect the predictions?

First, it is not known to what extent recruitment rates have changed, but it seems quite apparent that they have not remained constant, particularly in the GBLMI region. In the mid-1960's, Anderson and Hamerstrom (1967) noted that cormorants typically nested in an area for 1 to 26 years and then moved out and colonized another location. Thirty years later, a similar population dynamic has become evident at inland sites: some large inland sites (Crex Meadows–Fish Lake WLA's, Grand River Marsh, and Pool 8, and Ballard Island on the Mississippi River) no longer support cormorants, and DCCO's have declined considerably in number at other inland sites (Trempealeau NWR, Mead WLA), whereas a large increase has occurred in the GBLMI.

Second, competition with gulls for nesting habitat has not materialized to any large extent. At Gull Island, which has a sizable herring gull *(Larus argentatus)* population, and on some of the Lake Michigan islands, where numbers of breeding ring-billed gulls *(L. delawarensis)* are high, competition may be a limiting factor. In some localized situations, competition for habitat with bald eagles *(Haliaeetus leucocephalus)*, whose breeding population has recovered and is increasing in the State, may influence DCCO nesting success. This occurred at the Fish Lake WLA in Burnett County in 1983, when an adult bald eagle pair, using artificial poles and platforms as roosting sites, may have predated cormorant nests. The presence of the eagles totally disrupted DCCO nesting activities at the colony and led to abandonment of the colony with no young produced. This pair had coexisted with cormorants on the same flowage for several years, but the eagles' nest blew down in November 1982 (Hoefler and Kooiker 1983).

Relative food availability is likely a third factor influencing the continuing cormorant population increases. Cormorants are opportunistic feeders that prey on the most available fish species present—generally 15–30 cm long (Weseloh et al. 1995) in shallow waters, shoals, and in midwaters (Craven and Lev 1987, Ludwig and Summer 1997), although historically on Lake Michigan they may have fed also in deeper waters (Ludwig and Summer 1997). Craven and Lev (1987) found that ninespine stickleback *(Pungitius pungitius)* and four other small forage species predominated in cormorant diets in the API. Cormorant food-habits studies conducted in lower Green Bay during 1983, 1993, and 1997 revealed that the alewife was predominant (Brian Belonger, Cliff Kraft, and Thomas Erdman, pers. commun.)

The alewife first appeared in Lake Michigan in 1949, was common by 1957, and exploded in number during the late 1950's and early 1960's (Becker 1983), when the region's cormorant population was depressed. As cormorant populations began to recover, the alewife was abundant and dominated the lake's fishery especially because predatory lake trout *(Salvelinus namaycush namaycush)* populations had crashed on the upper Great Lakes as the result of overfishing, sea lamprey *(Petromyzon marinus)* predation, parasitism (Weseloh et al. 1995), and poor or no reproductive success due to the effects of polychlorinated biphenyl (PCB) contamination (Thomas Erdman, pers. commun.). When alewives are abundant, reproduction rates and survival of fledged cormorant young may both be high; that scenario enhances DCCO recruitment (Weseloh and Ewins 1994).

Breeding habitat—a fourth factor that may affect cormorant populations—has not proven limiting in Wisconsin. Ludwig and Summer (1997) pointed out that Civilian Conservation Corps projects of the 1930's created many flooded inland impoundments across northern Michigan and Wisconsin through the installation of low-head dams. These impoundments, which simulated a wetland type in the Canadian prairie provinces inhabited by large numbers of breeding cormorants, became breeding refugia for cormorants during World War II. These were the sites where cormorants barely hung on during the DDT era (Ludwig 1984). These impoundments—flowages—provided ample habitat for cormorant recolonization across north-central, central, and northwestern Wisconsin beginning in the 1970's.

The loss, and in some cases complete disappearance, of nesting trees on Lake Michigan islands, due to a combination of blowdowns, high water levels and seiches, and cormorant excreta killing vegetation, opened up ground habitats for more nesting cormorants during the 1980's and 1990's. Ground nesting is especially evident on Cat Island in lower Green Bay and on Jack Island, Hat Island, and the Spider Islands off the Door County peninsula. In 1997, some island sites on Lake Michigan appeared to be reaching carrying capacity, but, analogous to the status of colonies in the Les Cheneaux Islands, Lake Michigan (Ludwig and Summer 1997), until mortality rates exceed reproductive success rates statewide, the State's breeding population will continue to increase.

Management Implications

In sharp contrast to the 1970's and early 1980's, when State and Federal management efforts were focused on providing artificial nesting structures, the need to enhance or maintain cormorant populations has been obviated, except at the Mead WLA. With a species that is fully recovered in the State, attention has shifted in the opposite direction to questions of control owing to concerns regarding the impacts of cormorants on commercial and sport fisheries, particularly yellow perch on Lake Michigan. Except for research indicating that DCCO predation on smallmouth bass *(Micropterus dolomieu)* in the eastern basin of Lake Ontario is "excessive," (Schneider et al. 1999), recent studies (Craven and Lev 1987, Ludwig et al. 1989, Madenjian and Gabrey 1994 and 1995, Diana et al. 1997, Ludwig and Summer 1997, Maruca et al. 1997) have demonstrated that breeding cormorants have not had a significant impact on Lake Michigan and other Great Lakes' commercial and sport fisheries. Yellow perch, a major focus of concern on Lake Michigan and on the lower Great Lakes, are sometimes abundantly represented in DCCO diets (Brian Belonger, pers. commun.; Neuman et al. 1997), although with seasonal and yearly variations (Maruca et al. 1997). In contrast to concerns about declining Lake Michigan perch populations, most likely because of years of recruitment failures (Diana and Maruca 1997), Brazner (1997) found that yellow perch (primarily young of the year) was among the most important species in fish assemblages sampled at Green Bay coastal wetland sites.

In the Wisconsin waters of Lake Superior, where there were at one time as many as 40 pound nets in operation for whitefish, the combination of a depressed whitefish market in the early to mid-1980's and the frequent occurrence of cormorants at the nets caused commercial fishermen to all but abandon pound nets and switch to trap nets (Bruce Swanson, pers. commun.). Foraging cormorants in the API, initially attracted to pound-net structures as perching sites, stopped being a point of contention for managers in this region after the mid-1980's.

Perceptions of cormorants as a serious nuisance persist in Wisconsin. In 1997, individuals on Wisconsin Lake Michigan islands undertook efforts to conduct their own cormorant management, including hanging wind chimes and monofilament lines to discourage cormorants from nesting at one island. In 1995, two domesticated pigs were turned loose on another Green Bay island, ostensibly to disrupt nesting attempts. The cormorants nested in trees (northern white-cedar *[Thuja occidentalis])* and largely ignored the pigs. The pigs, however, altered the island's plant community, and the following spring their carcasses were found side by side. No doubt such independent management efforts will continue as long as the DCCO is perceived as a threat to Lake Michigan fisheries, at least until State and Federal agencies embrace the same view and, if deemed necessary, take concerted action themselves.

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Directory of Personal Communications

Brian Belonger
Wisconsin Dept. of Natural Resources
Peshtigo Service Center
101 N. Ogden Road
P.O. Box 208
Pestigo, WI 54157

Clifford E. Kraft
Cornell University
Dept. of Natural Resources
206F Fernow Hall
Ithaca, NY 14853

Thomas Erdman
Richter Museum of Natural History
University of Wisconsin–Green Bay
2420 Nicolet Drive
Green Bay, WI 54311–7001

Brian Peters
Mead Wildlife Area
Wisconsin Dept. of Natural Resources
52148 County Highway S
Milladore, WI 54454

Michael D. Staggs, Director
Bureau of Fisheries Management
and Habitat Protection
Wisconsin Dept. of Natural Resources
101 S. Webster Street
Madison, WI 53707

Bruce Swanson
Wisconsin Dept. of Natural Resources
Park Falls Office
875 S. 4th Avenue
Park Falls, WI 54552

Stanley Temple
University of Wisconsin–Madison
Dept. Of Wildlife Ecology
1630 Linden Drive
Madison, WI 53706

Appendix A—Number of Wisconsin double-crested cormorant nests, by colony site, region, and year, 1973–97

Colony site	Region	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Gull Island	API	0	0	0	0	0	17	41	53	128	210	243	254	289	374	378	351	396	A	520	A	589	602	A	569	416
Naden's Point	API	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Eagle Island	API	0	0	0	0	0	0	0	0	0	0	0	4	13	29	36	61	83	A	137	A	A	133	A	A	151
Phantom Flowage, Crex Meadows Wildlife Area	BUCA	23	18	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grettum Flowage, Fish Lake Wildlife Area	BUCA	X	5	12	19	19	19	26	39	47	58	A	A	29	0	0	0	0	0	0	0	0	0	0	0	0
Spook Lake	BUCA	0	0	0	0	0	0	0	0	0	0	0	X	6	X	0	0	0	0	0	0	0	0	0	0	0
Tucker Lake	BUCA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Amsterdam Sloughs	BUCA	0	0	0	0	0	0	0	0	0	0	X	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Chequamegon Waters–Miller Dam Flowage	CE–NC	0	0	0	0	0	0	0	0	0	0	0	36	15	0	0	0	0	0	0	0	0	0	0	0	0
La Grange Flowage	CE–NC	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CWCA	CE–NC	0	0	0	0	0	0	0	X	X	10	A	A	11	12	14	X	0	0	0	0	0	0	0	0	0
Sportsman's Lake	CE–NC	0	0	0	0	0	0	0	2	5	15	0	0	1	8	12	A	A	A	A	A	20	0	0	0	0
Berkhahn (Townline) Flowage, Mead Wildlife Area	CE–NC	20	39	41	51	67	118	124	218	223	222	285	364	327	390	355	147	185	251	A	201	193	166	A	A	114
Teal Flowage, Mead Wildlife Area	CE–NC	0	0	0	0	0	0	0	0	12	93	76	65	69	58	56	31	49	A	A	80	87	99	A	A	113
The Reservoir, McMillan Wildlife Area	CE–NC	0	0	0	0	0	0	0	0	6	11	4	5	7	13	16	16	11	0	0	0	0	0	0	0	0
Big Lake, Meadow Valley Wildlife Area	CE–NC	0	0	0	0	0	0	0	0	0	2	A	4	A	X	X	0	0	0	0	0	0	0	0	0	0
Turner Creek Cranberry Flowage	CE–NC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X	139
Grand River Marsh Wildlife Area	EACE	23	35	48	11	A	76	100	75	78	65	64	68	68	14	13	0	0	0	0	0	0	0	0	0	0
S. C. Dredge Bank Island, Lake Puckaway	EACE	0	0	0	0	0	0	0	0	0	0	0	0	10	96	130	95	A	A	A	A	383	385	A	A	306
E. Dredge Bank Island, Lake Puckaway	EACE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	A	A	A	A	55	A	A	A	153
Four Mile Island, Horicon Marsh Wildlife Area	EACE	0	0	0	0	0	0	30	0	0	0	0	0	0	22	52	35	A	24	48	41	109	11	0	0	0
Cotton Island, Horicon Marsh Wildlife Area	EACE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	A	A	46
Main Pool, Horicon Marsh National Wildlife Refuge	EACE	0	0	0	0	0	0	30	27	A	34	48	120	150	180	46	0	0	0	10	10	15	14	18	20	13
Colleins Ditch, Horicon Marsh National Wildlife Refuge	EACE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	A	42	85

Appendix A—Continued

Colony site	Region	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Unit I–5, Horicon Marsh National Wildlife Refuge	EACE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	14	6	3	5	105
South Oconto Marsh	GBLMI	0	0	0	0	0	0	0	0	0	0	0	0	8	10	7	X	0	0	0	0	0	0	0	62	0
Fish Island	GBLMI	0	0	0	18	50	54	A	61	A	42	29	23	19	A	6	X	0	0	0	0	11	A	A	A	5
Gravel Island	GBLMI	0	0	0	0	0	17	A	37	A	A	81	93	166	232	79	A	33	X	X	0	0	0	0	0	0
Spider Islands	GBLMI	0	0	0	0	0	0	X	60	123	203	254	361	455	588	967	A	1,238	1,410	2,100	1,835	2,254	3,455	2,615	3,440	3,865
Green Island	GBLMI	0	0	0	0	0	0	X	X	X	X	10	A	3	0	0	0	0	0	0	0	0	0	0	0	0
Jack Island	GBLMI	0	0	0	0	0	0	0	0	24	35	58	58	71	97	82	A	250	A	A	123	249	353	A	A	1,154
Hat Island	GBLMI	0	0	0	0	0	0	0	0	7	0	0	0	0	8	43	A	27	A	A	428	582	1,188	A	A	1,457
Cat Island Chain	GBLMI	0	7	7	19	18	34	109	200	250	A	516	364	413	722	762	1,022	1,063	914	866	702	1,425	1,332	A	A	2,126
Lone Tree Island	GBLMI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	0	0	0	0	0	X	X	3
Hog Island	GBLMI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	5	X	X	0	54	A	A	A	8
Pilot Island	GBLMI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	0	0	50	295	329	A	A	247
Strawberry Island	GBLMI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	126	X	X	5
Little Tail Point	GBLMI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	0	0	0	0	0	0	0	0	0	0
Big Sister Island	GBLMI	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trempealeau National Wildlife Refuge (formerly Delta Fish and Fur Farm)	UMISS	0	0	0	13	7	10	A	20	43	28	62	68	69	57	65	75	A	50	29	37	A	14	A	A	12
Pool 8	UMISS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	36	15	X	X	0	0	0	0
Ballard Island	UMISS	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X	X	19	A	14	A	5	0	0	0	0
Ambrough Slough (Vogt Lake)	UMISS	0	0	0	0	0	0	0	0	0	0	4	9	15	4	0	X	4	X	X	X	15	13	0	0	0
Mertes (St. Mary's) Slough	UMISS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X	25	13	5	0	13	3
Smith Slough	UMISS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X	X	3	6	5	10	20
Lake Onalaska	UMISS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	90	X	X	X	X	0	0	0	0
Total number of nests		66	104	121	131	161	345	460	792	955	1,028	1,734	1,903	2,214	2,961	3,143	1,863	3,515	2,685	3,739	3,637	6,481	8,238	2,641	4,161	10,546

Key: A = Colony known to be active but not surveyed; API = Apostle Islands, Lake Superior;
BUCA = Burnett County Area, northwestern Wisconsin; CE–NC = central and north-central Wisconsin;
EACE = east-central Wisconsin; GBLMI = Green Bay Lake Michigan Islands;
UMISS = upper Mississippi River; X = no survey conducted.

Appendix B—Productivity[1] of double-crested cormorants in Wisconsin by region, 1973–97

Year	API	BUCA	CE–NC	EACE	GBLMI	UMISS
1973	SNA	—	—	—	—	SNA
1974	SNA	—	2.38(39,1)	—	—	SNA
1975	SNA	—	1.27(41,1)	—	0.43(7,1)	SNA
1976	SNA	—	2.39(51,1)	—	0.68(19,1)	0.00(13,1)
1977	SNA	—	2.85(67,1)	—	0.00(18,1)	—
1978	—	—	1.94(118,1)	—	1.76(34,1)	1.20(10,1)
1979	1.15(41,1)	—	1.97(154,2)	1.67(30,1)	—	—
1980	—	—	2.39(218,1)	1.27(75,1)	1.25(200,1)	—
1981	—	1.91(47,1)	2.27(229,2)	—	1.60(250,1)	0.00(43,1)
1982	—	1.90(58,1)	2.16(343,5)	—	—	1.07(28,1)
1983	0.73(243,1)	—	1.87(365,3)	0.73(64,1)	1.99(938,6)	2.00(66,2)
1984	1.65(258,2)	0.00(100,1)	1.93(434,3)	1.67(120,1)	1.70(899,5)	2.36(70,1)
1985	1.70(302,2)	0.00(29,1)	1.80(408,4)	—	1.44(640,3)	2.27(84,2)
1986	1.59(403,2)	SA	1.28(481,5)	—	1.65(820,2)	0.37(19,2)
1987	1.45(414,2)	SNA	2.07(439,4)	—	1.60(1128,3)	1.75(65,1)
1988	—	SNA	1.74(194,3)	1.86(35,1)	—	—
1989	1.99(173,2)	SNA	0.00(185,1)	—	3.26(463,1)	—
1990	—	SNA	0.00(251,1)	2.37(24,1)	2.93(921,1)	—
1991	0.25(520,1)	SNA	0.00(?,1)	3.10(48,1)	—	—
1992	[2]	SNA	0.78(281,2)	2.63(41,1)	—	—
1993	—	SNA	1.29(280,2)	1.72(109,1)	—	—
1994	1.02(602,1)	SNA	1.64(31,1)	2.12(25,2)	1.80(711,3)	1.71(14,1)
1995	—	SNA	0.00(?,1)	—	2.00(160,1)	—
1996	—	SNA	—	—	—	1.56(23,2)
1997	1.45(416,1)	SNA	—	1.21(48,1)	1.16(3865,1)	—

API = Apostle Islands, Lake Superior; BUCA = Burnett County area, northwestern Wisconsin; CE–NC = central and north-central Wisconsin; EACE = east-central Wisconsin; GBLMI = Green Bay and Lake Michigan islands; UMISS = upper Mississippi River; SA = sites abandoned; and SNA = sites not active.

[1] Decimal numbers indicate mean number of young per nesting pair. Numbers in parentheses represent number of nests sampled and number of colonies.

[2] Newcastle disease present on Gull Island, API; 262 young buried on site; no data on production of young.